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Report No. 8926-146

Material - Aluminum - Steel, Alloy

Electromotive Potentials

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Abstract:

A literature survey was made on electrochemical corrosion as related to aircraft fabrication materials. Electrochemical corrosion problems and testing methods were emphasized in the literature survey. In addition, the electromotive potentials of several aircraft materials were determined and are presented.

Reference: Hooper, A. F., George, J. C., Keller, E. E., "Investigation of Electrochemical Corrosion As Applied To Aircraft," General Dynamics/ Convair Report MP 58-425, San Diego, California, 9 April 1959. (Reference attached).

STRUCTURES & MATERIALS LABORATORIES

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A DIVISION OF GENERAL DYNAMICS CORPORATION

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REPORT NO. MP-58-425

INVESTIGATION
OF
ELECTROCHEMICAL CORROSION
AS APPLIED TO AIRCRAFT

MODEL: REA 7038

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INTRODUCTION:

Corrosion denotes the destruction of a metal by chemical or electrochemical action in contrast to erosion which signifies the destruction of a metal by mechanical action.[10] Direct chemical corrosion attack on a metal involves a reaction between a metal and other elements or compounds. The most common chemical corrosion attack known is the oxidation of metal to form oxide films. Certain metals and alloys oxidize to form continuous inherent thin films. The corrosion characteristics of these films are an intrinsic property of the metal.[11,16] Other metals and alloys oxidize to form heavy oxide films which crack due to compressive stresses, and oxidation of the base metal alloy continues. Some types of chemical corrosive action, such as the first one mentioned above, are beneficial to the corrosion resistance of certain metal alloys.[2,10,17]

Electrochemical corrosion is an oxidation-reduction reaction between adjacent metal surface areas in an aqueous solution (the electrolyte). The basic requirements are always: (1) differences in potential between adjacent areas on a metal surface or surfaces to provide anodes and cathodes; (2) moisture to provide an electrolyte; (3) a corroding agent to be reduced at the cathode, and (4) an electrical path in the metal for electron flow from anodes to cathodes.[12] The above requirements are basic for the electrochemical corrosion reaction, but the mechanisms and corrosion rates are much more complex. The fundamentals of mechanisms such as polarization, potential-pH relationships, overvoltage, passivity, activity, etc., are not completely known.[14]

There has been considerable progress in the development of new and better corrosion resistance materials, in defining and extending the boundaries of their usefulness, and in protecting materials from attack where their natural resistance to an environment has not been adequate. Most of this progress has been the result of empirical approaches. Much remains to be discovered by fundamental studies of corrosion processes, so as to provide a more substantial basis for even further progress in new as well as old directions.

OBJECT:

To make a literature survey in the field of electrochemical corrosion, and to list areas in which Convair research work would be most beneficial.

To determine the solution potentials of various new metallic materials currently used in aircraft design.

CONCLUSIONS:

1. Literature survey work indicates that areas in which research work would be most beneficial include the following:

CONCLUSIONS: (Continued)

(a) High temperature corrosion work.

(b) Electrochemical studies involving the fundamental mechanism of polarization.

(c) Studies of inhibitors, activators, cleaners and passivators using radioisotopes.

(d) Cathodic protection studies using an applied potential.

2. The solution potential of 7079-T6 aluminum alloy was found to be slightly anodic to the other high strength aluminum alloys. The solution potentials of the other alloys were found to be nearly the same as the solution potentials of alloys of similar chemical composition.

TEST PROCEDURE:

1. Literature Survey

A literature survey was made on electrochemical corrosion as related to aircraft fabrication materials. Electrochemical corrosion problems and testing methods were emphasized in the literature survey.

Several local aircraft companies were contacted to determine their position and activity in the field of corrosion research work. In general, questions were asked concerning the type of corrosion research work each company was performing or planning to perform in the near future.

2. Laboratory Test Work on Solution Potentials

The solution potentials of several metallic aircraft materials (Table I) were obtained on a voltmeter-potentiometer system as shown in Figure 1. All of the metallic electrodes were solvent cleaned with methyl ethyl ketone and aliphatic naphtha. The aluminum alloy electrode surfaces were chemically cleaned with "Oakite #34" deoxidizer. The steel electrode surfaces were chemically cleaned with 15% hydrochloric acid, and the zinc electrode surfaces were chemically cleaned with a solution of 20% nitric acid. The solution potentials of the above metallic materials were obtained in a standard electrolyte of 53 g. NaCl, and 3 g. H_2O_2 per liter of distilled water. The solution potentials were obtained at 77± .5°F. using a silver-silver chloride reference electrode.

RESULTS & DISCUSSION:

1. Results of Literature Survey

The majority of corrosion reactions are electrochemical in nature; therefore, corrosion research has been concentrated in this field. The literature material available in the field of electrochemical corrosion covers a vast source of information, which could only be touched-upon during this test program. The more recent reference material stresses the need for studying the basic fundamentals and mechanisms of electrochemical corrosion reactions.

Electrochemical corrosion occurs when a difference in potential exists from one point to another on the surface of a metal or between metals in the presence of a corrosive solution (the electrolyte). Current will flow through the solution from the point of high potential (the anode) to a point of low potential (the cathode). The amount of metal dissolved at the anode is proportional to the quantity of current flowing in the circuit. The effective differences in potential are equal to the solution potential of the anode area minus that of the cathode area, less the back potentials generated at both the anode and cathode by the flow of the corrosion current.[10,21] The resulting corrosion mechanism is much more complex and varies due to many factors common to the corrosive reaction.

One or a combination of the following factors can influence or cause a corrosive reaction.[18]

A. Factors associated mainly with the metal.

1) Effective electrode potential of a metal in a solution.
2) Overvoltage of hydrogen on the metal.
3) Chemical and physical homogeneity of the metal surface.
4) Inherent ability to form an insoluble protective film.

B. Factors which vary mainly with the environment.

1) Hydrogen-ion activity (pH) in the solution.
2) Specific nature, concentration, and distribution of the other ions in solution.
3) Influence of oxygen in solution adjacent to the metal surface.
4) Rate of flow of the solution in contact with the metal surface.
5) Ability of environment to form a protective deposit on the metal.
6) Temperature.
7) Static or cyclic stresses.
8) Contact between dissimilar metals or other material as effecting localized corrosion.

ACCESS NO.

Title: MATERIAL - ALUMINUM - STEEL, ALLOY. ELECTROMOTIVE POTENTIALS.

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9 pages, 1 table, 1 figure, 21 references.

RESULTS & DISCUSSION: (Continued)

1. Results of Literature Survey (Contd)

This list of influencing factors is not complete, nor have they been listed according to their relative importance or influence on electrochemical corrosion reactions.

The relationships of the fundamentals and mechanisms of electrochemical corrosion reactions which are influenced by the above factors need to be studied to determine the characteristics of corrosion rates.[3, 7, 19] Such electrochemical corrosion phenomena as polarization, overvoltage, potential-pH relationship, passivity, activity, etc., which give metals certain corrosion characteristics should be studied to determine their fundamental mechanisms.[14]

A research program could be developed to study the basic fundamental mechanisms of such a phenomenon as polarization.[4,5]

Many types of electrochemical corrosion reactions are controlled by anodic or cathodic polarization reactions.[1] The study of polarization will necessitate a proper understanding of the overall corrosion reaction and how reduction in corrosion can be accomplished most readily and reliably. Knowing the fundamental mechanisms of a polarization reaction and the controlling factors can aid in a systematic solution to preventing electrochemical corrosion reactions.

Aircraft design necessitates the use of numerous metallic combinations due to structural and weight requirements of an airframe. These metallic combinations present undesirable corrosion conditions which must be stifled by the most feasible preventative methods.[13,17,20] The present corrosion preventative methods used in aircraft design are not completely fool-proof and some corrosion does occur.[6,9]

Several aircraft companies on the West Coast were contacted to determine their status in the field of corrosion research. None of the aircraft companies had any plans for an organized research and development program in the corrosion field for the year of 1959, except North American Aviation, Incorporated. Several of the aircraft companies did emphasize the need for a research program in the field of electrochemical corrosion on aircraft fabrication materials.

North American Aviation, Incorporated is presently planning a high temperature corrosion program for the year of 1959. This program will evaluate several magnesium, aluminum, and high temperature alloy couples in the temperature range of 450° to 800°F. This high temperature corrosion program will also evaluate the effect of exotic fuels, finish systems, chemical surface treatments and metal fasteners on these couples in the above temperature range.

RESULTS & DISCUSSION: (Continued)

2. Results of Laboratories Test Work on Solution Potentials

The solution potentials of several metallic aircraft fabrication materials under consideration are tabulated in Table I. The results of solution potential measurements on 7079-T6 aluminum alloy indicate that this alloy is slightly anodic to other aluminum alloys such as 2024-T4 and 7075-T6. The solution potentials of the other alloys tested correlate with the results of similar alloys found in the literature.[15]

NOTE: The data from which this report was prepared are recorded in Engineering Test Laboratory Data Book 3028.

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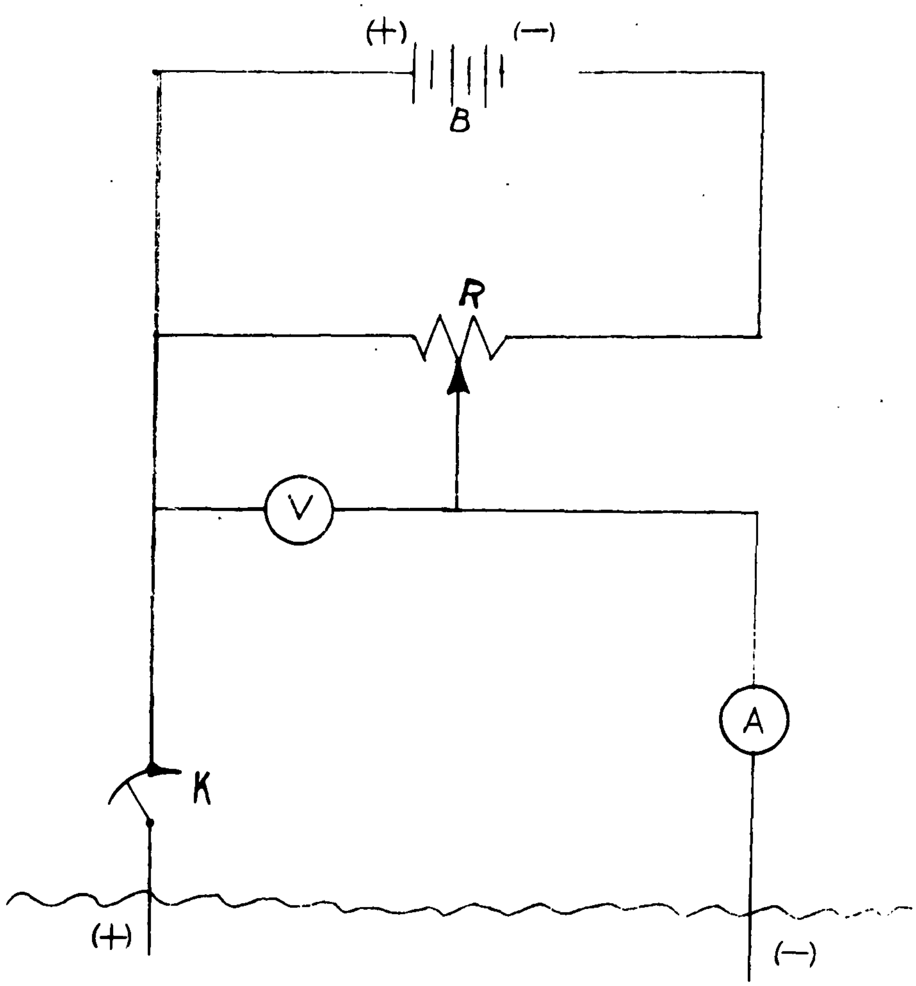

A - Galvanometer
B - Operating Cell
K - Key
V - Voltmeter
R - Variable Resistor

FIGURE 1

Table I Metal Alloy Solution Potentials
25°C Solution: 53g NaCl,3g H_2O_2/liter

Metal Alloys	Solution Potential, Volt Ag/Ag Cl Reference Electrode*
2024-T4 Aluminum Alloy	0.56
Cladding(1230) of 2024-T4 Aluminum Alloy	0.72
7075-T6 Aluminum Alloy	0.75
Cladding(7072) 7075-T6 Aluminum Alloy	0.87
Zinc(C.P.)	0.98
6061-T4 Aluminum Alloy	0.67
6063-S Aluminum Alloy	0.73
3003-S Aluminum Alloy	0.74
7079-T6 Aluminum Alloy	0.83
4130 Steel	0.44
Vasco Jet 1000 Steel	0.45

* The Solution Potentials Listed May be Converted to N/10 Calomel by Adding 0.11 Volts

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